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PATTERNS OF UNIVERSITIES-FIRMS INTERACTION IN BRAZIL IN FOUR INDUSTRIAL SECTORS

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ABSTRACT:This paper investigates university-firms interactions in Brazil four industrial sectors. The sectors analyzed are: chemical and drugs, metal-mechanics, electro-electronics and wood and furniture. The investigation is based in information from firms innovative patterns from Brazilian Industrial Survey of Technological Innovation (PINTEC) and from interactive research groups from National Counsel of Technological and Scientific Development (CNPq's) Directory of Research Groups. The results points to specific features in terms of university-firms interactions in each industrial sector, what suggest that this type of investigation should take in account the National and Sector frameworks of Innovation Systems.

KEY-WORDS: university-firms interactions, sectorial patterns, CNPq, PINTEC, Brazil**.**

JEL Classification**:** O33 - Technological Change: Choices and Consequences; Diffusion

RESUMO: Esse trabalho investiga a relação universidade-empresa em quatro setores industriais da indústria brasileira. Os setores são: químico/farmacêutico, metal-mecânico, eletro-eletrônico e móveis e madeira. A investigação esta baseada em informações da Pesquisa de Inovação Tecnológica do Brasil (PINTEC) e dos gruspos de pesquisa interativos do Diretório dos Grupos de Pesquisa do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Os resultados apontam características específicas da relação universidade empresa nesses setores, o que sugere que esse tipo de investigação deve ser levada em conta nas analises de sistemas nacionais e setoriais de inovação.

PALAVRAS-CHAVE: interação universidade-empresa, padrões setoriais, CNPq, PINTEC, Brasil.

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INTRODUCTION

The main focus of the paper is the sectorial pattern of relationships established between Universities and Industry in Brazil. These interactions are understood as part of a broader set of relationships among different elements that constitute the institutional basis of the National System of Innovation (NSI)[3], which might influenced the pattern and the intensity of learning mechanisms to the industrial firms. The paper is developed from an evolutionary perspective, in which those interactions perform a central role to the dynamics of NISs, being the product of hereditary organizational routines[4] developed by industrial firms. Those routines tend to be reproduced in the future, affecting the pattern through which the NSIs evolve along time. The normative relevance of the analysis comes from this perspective.

The new Science and Technology (S&T) policies that have been implemented by different countries have a particular focus on interactions between universities, research institutes and industrial firms. In this context, the universities are undergoing a cultural transformation to play a significant role in knowledge-based society as an important agent in the promotion of regional development. Under the concept of National System of Innovations it is understood that university-industry interactions are an element extremely important of a wider institutional set, responsible for the creation of stimulus to technological progress and to construction of productive and innovative competences at regional and national levels. In Brazil, some universities are well positioned to become full-fledged partners in national innovation systems and to contribute to economic development. From being largely institutions of advanced education and basic research, universities are increasingly expected to contribute directly to commercial activity and economic development, incorporating a “third mission” based on university-industry research partnerships (Etzkowitz and Leydesdorff, 2000). The two traditional missions of universities – advanced education and research – are also equally important to NISs and are under similar pressure to adapt to new realities.

The development of an inquiry about the pattern of interactions between universities and industrial firms seems to show particularly sectorial features that should be taken in account. As pointed by the seminal paper of Pavitt (1984) industries differs in terms of its innovation patterns. The present paper analyses how innovative firms decide to cooperate with Brazilian universities in the development of their products and processes. The analysis is based on information obtained for four different sectors of economic activity, stressing the main types of relations established between research groups, inserted or not in university, and Brazilian firms. Specifically, information about the types of relations that have been considered relevant by innovative firms are explored, in order to discus the characteristics of university-industry relations in different sectors. The objective is to understand how the innovative strategies adopted by firms differ across industrial sectors, and, simultaneously, understand the role performed by different research groups inserted in universities to the strengthening of sectorial systems of innovation. A strong diversity in terms of university-industry interactions is expected to be observed given the great specificity of sectors’ analyzes.

[3] National System of Innovations may be understood as the set of institutions, actors and mechanisms in a region or country that contribute to the development, advancement and dissemination of technological innovations.
[4] Organizational routines are understood as a regular and previsible behavior developed through the practical experience in the orbit of production, which conduct to regular procedures of decision taking and the consolidation of coherent entrepreneurial strategies (Nelson and Winter, 1982)..

The study defines a proxy of the relations established between innovative firms and research groups, based on the information extracted from three databases: (i) data about innovative efforts of Brazilian firm collected by Industrial Survey of Technological Innovation (PINTEC), elaborated since 2000 by the Brazilian Institute of Geography & Statistics (IBGE); (ii) information obtained in Directory of Research Groups maintained by the National Council of Scientific and Technological Development (CNPq); (iii) information from a survey applied to research group's leaders about the technology transferred to firms. The data extracted from CNPq's Directory contains a detailed description about the links established between those groups and the productive sector, including information about knowledge channels and technology transfer.

The paper is organized in five sections. The first discusses theoretical issues and current trends of university-industry interactions. The second section attempts to summarize recent evaluations of university-industry interactions in Brazil. The third section presents the methodology used in the study and discusses the characteristics and limitations of the data base. The fourth section presents an analysis of the information extracted from the data base, considering the sectorial specificities of university-industry interactions. Finally, the fifth section presents the main conclusions of the study.

1. INNOVATION SYSTEMS AND UNIVERSITY-INDUSTRY INTERACTIONS: ANALYTICAL UNFOLDING

The first explicit definition of National System of Innovation (NSI) might be retraced to the work of Freeman (1987), which analyzed the process of Japanese growth in period 1945-1980. Freeman stressed that the Japanese growth could not be explained without consider the emphasis given by Japanese society to qualitative systemic factors that affected the innovation process. These factors would be related to the construction of social networks among different institutions in the public and private sectors, generating interactions from which new technologies are developed, incremented and diffused (Freeman, 1988). Other authors, especially Lundvall (1992) and Nelson (1994), had contributed to the development of NSI concept, developing an effort to systemize the dynamics of the innovation and emphasizing the main aspects that affect the performance of NSIs in different countries.

From these contributions, two variants of the concept of NSI might be stressed, both constructed from the hypothesis that the innovative processes in the companies are the product of collective efforts. Nelson and Rosenberg (1993) presented a more restricted conception of the NSIs in which the focus remains in the systemic relations between R&D efforts developed by industrial companies, the role of S&T organizations, such as universities, and the S&T policies explicitly oriented. However, they alerted that the institutional interactions do not presume that the system is conscientiously projected, or that the activities developed by institutions inserted in NSIs are coherently connected. According to those authors, the NSI concept would facilitate the realization of empirical studies, being defined as structures that might influence the strengthening of national technological capacities and the process of technological development. In this direction, they stand out that companies, research laboratories, universities, as well as governmental research centers, are important elements of these structures.

The broader concept of NSI developed by Freeman (1987) and Lundvall (1992) incorporates the ample set of institutions that affect directly and indirectly the innovative strategies and the innovative performance of firms. Different institutions and specific organizations of each country, such as, for example, the financial sector and the educational system, are characterized as critical elements of the NSI. However, it would be the interactive learning and the specific character of the process of innovation the central elements that might be stressed to the understanding of the innovative dynamics. In this perspective, the knowledge becomes the basic resource that might be mobilized to accelerate the process of economic development. The economic success of individuals, companies or economies would be directly related to its capacities to integrate different kind of knowledge and to construct new competences and not only to the access to the relevant information. According to Lundvall (1992) a system of innovations would be constituted by elements and relationships that interact in the production, diffusion and use of new and economically useful knowledge. In this sense, a national innovation system comprehends elements and relationships located inside the limits of a sovereign nation. Beyond the laboratories of R&D, Lundvall (2001) also stress the importance of innovative activities articulated to the learning developed by firms from internal routines and from different learning practices, such as learning by doing, learning by interacting and learning by using. In this process, experiences are accumulated, with particular institutions - incorporated in routines, procedures and norms – acting to reduce the intrinsic uncertainty associated with the innovative process in the context of each NSI. More recently, Lundvall and the Aalborg group have been concerned with another important elements of the NSIs, such as the process of construction of competences (related to the education and the training), as well as with inter and intra industrial relationships and with the dynamics of the job market (Lundvall, 2007).

The intensity and the form assumed by interactions between university and industrial firms, understood as an institutional set of elements that affect the generation and the diffusion of knowledge, varies according to specific characteristics of the environment in which they are inserted. They are affected by the level of internal cohesion of the S&T infrastructure and, on the other hand, by the capacity of industrial firms absorbing external knowledge. These interactions can be seemed as a two-way process (Mayer-Krammer and Schmoch, 1998) trough which technical and scientific knowledge is converted in new products and new processes. This process is characterized by the presence of path-dependencies of U-I relationships, especially those crated by demands of the industrial sector to the S&T infra-structure and by the institutional construction of a university system articulated with the industrial world.

In this sense, the understanding of peculiar dimensions of the learning processes has stimulated the creation of new concepts and of a analytical unfolding able to capture the different dimensions of a innovative dynamics anchored in U-I interactions. Sectorial determinants of this process had been analyzed by Bresci and Malerba (1992). Those authors introduced the concept of Sectorial Systems of Innovations (SSI) in which the size of the firms, their territorial localization and the level of competition faced by them (global, local, etc) are articulated in order to explain the generation and use of sectorial technologies. The main focus of the SSI approach relies on the nature, structure, organization and dynamics of innovation and production, stressing the importance of some key elements (firms, networks, institutions, demand and knowledge characteristics) and of some basic processes to the improvement of productive and innovative capabilities. According to Malerba (2002), the sectorial frontiers can include links and interdependences that are not well defined, moving constantly along time. In this perspective, the integration of complementary competences stimulates decisively the innovation process. Thus, considering the innovation as an interactive process between different agents, U-I interactions also become an important component of Sectorial Systems of Innovations.

The amplitude and intensity of the U-I interactions, on the part of the firms, are strongly associated with the perception of technological opportunities and with the appropriability conditions of innovative quasi-rents faced in each industrial sector (Klevorick et al., 1995). At the universities, these conditions also tend to vary according to specific characteristics of each scientific area (Saltin and Martin, 2001). So, the contribution of science to the innovative process tends to be compelled by sectorial specificities. According to the typology proposed by Pavitt (1984), the science based sectors would be characterized by the fact that innovations come directly from advances in scientific knowledge. The seminal work of Pavitt was followed by other analyses, based in distinct methodologies[5], which have tried to explore the analytical connections between scientific discoveries and the technological advances of the industrial world. These investigations reveal that the industrial sectors with stronger links with science tend to work with specific technological areas, such as genetic engineering, organic and inorganic chemistry, food technology, biotechnology, laser technologies and microelectronics (including telecommunications, electronic components and data processing). These areas tend to be more directly connected to some industrial sectors, such as chemical and petrochemical industries, pharmaceutical, electric equipment, electronic instruments, semiconductors, computers and aerospace. We can also mention some technological areas with a broader impact over different industrial sectors, such as computer sciences, new materials, general chemistry, informatics, metallurgy, physics and mathematics (Klevorick *et al.*,1995; Cohen *et al.*, 2002; Schartinger *et al.*,2002; Godin, 1996; Mansfield, 1991; Grupp, 1996).

However, not only technological specificities of industrial sectors but also some other factors might affect the intensity of interactive links between universities and firms. Among these factors we can stressed: (i) factors that are sector-specific, such as the characteristics of the industrial structure, the intensity of inter-firm competition and the presence of regulatory constraints; (ii) technology-specific factors, such as the stage of the life-cycle (Utterback and Suarez, 1993) and the complexity of the knowledge base (Malerba and Orsenigo, 1993) related to those technologies; (iii) institutional-specific factors, such as the role of technological policy and the availability of public research institutes; (iv) firm-specific factors, such as the origin of its capital, the focus of innovative strategies, the nature of the knowledge accumulated and the propensity to be involved in interactive links with others agents (Faulkner e Senker, 1994).

The intensity and quality of industry-science relationships has become extremely important and sophisticated in a knowledge economy, resulting in the consolidation of specific institutional set-ups and in a lot of different agreements between those spheres. As a consequence, these linkages have grown in importance as a central concern for government industrial policies. A comprehensive study developed by the OCDE (2005) shows that the development of formalized linkages – especially those that take the form of contract research, joint patents, licensing and spin-off – can be seem as a tip of an iceberg, in which the base is formed by a lot of informal contacts and by a mobility of researchers and information between the two spheres. Those linkages tend to become more complex due to the combined effect of some stylized factors (OCDE, 2005):

1) The acceleration of technical progress in areas where innovations are directly rooted in science (biotechnology, information technologies, new material, nanotechnologies, etc.)
2) The easier and cheaper exchange of information between researchers provided by new information technologies;

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[5] Among these methodologies we can mention: investigation of scientific articles mentioned in industrial patents, – the *non patent references* (Narin *et al.* 1997; Grupp, 1996); analyses of scientific fields exploited in articles elaborated by entrepreneurial researchers (Godin, 1996); structured investigations about the importance of scientific fields to the technological activities of industrial firms (Klevorick *et al.*, 1995; Mansfield, 1991; Cohen *et al.*, 2002) and interviews with academic researchers (Meyer-Kramer e Schmoch, 1998; Schartinger *et al.*, 2001 e 2002).

3) The increase of the external and multidisciplinary knowledge required to generate corporate innovation as well the huge competitive pressures to reduce R&D costs while seeking a rapid access to new and relevant information;
4) The ability to respond to new social needs that require the mobilization of complementary competences of the public and private research sectors;
5) Financial, regulatory and organizational changes that boosts the market for knowledge commercialization;
6) Restrictions on core public financing that encourage universities and others public research institutions to commercialize the results of theirs research activities, especially when they can build solid linkages with industry.

Research cooperation between industry and university has increased dramatically over the past few decades stimulated by a number of social forces, including shrinking federal support for research, pressures from global competitiveness and the increasing importance of science-based knowledge to the innovation process (Mowery and Sampat, 2005). There are also some evidences stressed by the modern literature of industry-science relationships about the importance of networks and clusters between those agents defined at a sub-national or local basis. In this sense, the most successful industry-science partnerships often involve links between universities or research institutes publicly financed and a cluster of local industries. Therefore, the promotion of industry-science relationships become an integral part of a networked based innovation policy strategy.

Particularly in the US, these tendencies can be associated with the decline of the competitiveness of the American industry since 1970’s, through a process of productivity slowdown that resulted in dramatic changes in U.S. National Innovation Policy. Among those changes, particular emphasis was attributed to the expansion of programs to support public-private partnerships (e.g., R&E Tax Credit, NSF-ERC and Advanced Technology Program-ATP). It’s also possible to observe a relaxation of antitrust enforcement to promote collaborative research between universities an industry (e.g., NCRA, NCRPA) as well as the implementation of policies formatted to promote a more rapid diffusion of federally-funded technologies from universities and federal labs to firms. Among those measures, the Bayh-Dole Act and the Wydler Technology Innovation Act in the 80’s were particularly important, giving to universities the possibility of owning the rights to technologies that arise from federal research grants. The Stevenson-Wydler Tecnhology Innovation Act determined the setting of technology transfer offices and the reserve of 0.05% of the research budget for technology transfer and the Bayh-Dole Act allowed researchers to apply for patents the results of public-sponsored research. Since the implementation of Bayh-Dole Act, almost all the biggest American universities have established a technology transfer or licensing office to boost the rapid growth in commercialization of university technologies. As a consequence, the number of U.S. University Patents increased from 300 in 1980 to 3.472 in 2004, while the number of Licensing Agreements had growth from 276 to 3,706 in the same period and the number of startups rose from 35 to 354. The institutional mechanisms that have been mobilized to stimulate university-industry knowledge flows involves co-authoring between academic and industry scientists, the establishment of industrial labs close to the universities, the consolidation of strategic alliances, research joint ventures (RJVs), licensing agreements, co-operative R&D Agreements (CRADAs) and industry consortia (such as SEMATECH) between universities and industry. NSF Industry-University Co-operative Research Centers and NSF Engineering Research Centers have also been mobilizes, as well as the construction of centers of excellence at the State-level.

Some of the more relevant empirical studies carried in developed countries stress the complexity of university-industry relationships. The *Carnegie Mellon Survey* (COHEN *et al.*,2002)) suggests that, even nowadays with all the fuss about ‘entrepreneurial universities’, the most significant ways under which knowledge is transmitted from public universities to industry are publications, seminars and conferences, training, informal contacts and, in a secondary position consulting. For a very small number of sectors patenting and licensing were important channels used by firms to access university information. These findings reiterate the point made by several other studies that claim that the main type of relationships between industry and public universities and labs are associated to the “open science”, and not mediated by the “market”. The PACE *Survey* (ARUNDEL & GEUNA, 2001) which investigated how large European innovating firms access the public research system, came to the same conclusion. According to the survey, hiring academic personnel is the most important instrument connecting university to industry (30.4% of total answers). Informal contacts came into second place (23.4%) and contract research in the third position (15.6%). In terms of sectors, firms in high-technology sectors prefer informal contacts and hiring personnel, while firms in low technology sectors prefer research contracts, access to conferences and codified knowledge such as publication.

2. UNIVERSITY-INDUSTRY INTERACTIONS IN BRAZIL

In Brazil, during the industrialization process the main obstacle to university- industry interactions was the lack of technology demand in firms’ productive process. The 80’s were characterized by some initiatives in this direction and in mid 1990 these initiatives have been adopted systematically, including government programs.

In the 90’s, the Industrial and Foreign Trade Policy had given a significant importance to the relationship between universities and enterprises towards technological modernization of the national industrial park and in increasing private sector shares in S&T investments (VELHO, 1996). Some federal special programs were created with the object to foster applied research and experimental development in engineering fields (RAPPEL, 1999). The biggest of them was a joint action of the Ministry of Science and Technology (MCT) and the Ministry of Education (MEC) that created the Cooperative Research Network Program (RECOPE) to stimulate and support the creation of networks of research institutions and businesses around cooperative projects. In the III Program to Support Scientific and Technological Development (PADCT) the Platform Project was designed to support the integration of efforts between universities, research institutes and industrial companies in the generation of cooperative projects[6].

In addition to these programs, were designed tax incentives to businesses for investment in R&D activities undertaken in partnership with universities or research institutions, through the Laws nº 8,248 in 1991 and nº 8,661 in 1993. This set of incentives, until September of 1995, benefited 27 technological development programs, being related to 26 isolated companies and to a consortium comprising 40 companies (SILVA & MAZZALI, 2001). In 2000, a project was set up to Law nº. 10,168 that regulates the creation of a sectorial fund (called Green and Yellow Fund) with the objective of encouraging interaction between universities and businesses towards Brazilian scientific and technological development. More recently, the “Innovation Law” (Law nº. 3,476 in 2004) was sanctioned in order to promote the investment of enterprises in scientific

[6] Among the 10 programs supported by PADCT in 1998, it should be mentioned the Program of Industrial Automation in Bahia that embraced 8 petrochemical industries and 2 universities, and generated 7 cooperative projects.

and technological research in the country. In the same year, the Law nº 10.973 was implemented to stimulate the interaction between Scientific and Technological Institutions (ICTs) and businesses[7].

In the different states of Brazilian Federation, there was also the creation of specific mechanisms to stimulate the cooperation of the academic community with the business sector, particularly through the mobilization of state's Foundations of the Research Support (FAP). The Foundation of the Research Support of Rio Grande do Sul (FAPERGS) launched, in 1989, the first program specifically designed to support U-I cooperative projects and, until 1998, funded around 200 projects (VARGAS et al., 1999). The São Paulo Foundation of the Research Support (FAPESP) has created "mechanisms to intensify the dissemination of knowledge, making it more accessible to the company" (CRUZ, 1999: p.235) with the creation of programs such as the Technological Innovation Partnership (PITE) and the Innovation in Small Enterprise (PIPE). More recently, some FAPs, through FINEP/MCT, established the Program to Support Enterprises' Research (PAPPE) with the objective of promoting the development of technology in enterprises, persuading them to come near to the institutions of education and research. Among the states already benefited from the PAPPE are Minas Gerais, Rio Grande do Sul, Rio de Janeiro, Bahia and Mato Grosso do Sul.

From industry side, there are some recent initiatives from the Edvaldo Lodi Institutes with the creation of the Technology Forum (ForumTec) in Ceará (1996), Bahia (1997) and Minas Gerais (2003) "whose goal is to articulate the institutions that make up the state S&T System, promoting the generation of cooperative projects that capture resources for local technological development" (RAPPEL, 1999:102). The National Association for Research and Development of Industrial Enterprises (ANPEI), created in 1984, has also done some initiatives towards bringing together industry and university.

Despite the increasingly sophistication of the institutional set-ups related to the support of U-I interactions, empirical evidences have showed that these interactions are still limited in Brazilian economy. Among problems identified in case studies that reflect inefficiencies and weaknesses in U-I interactions in the country, it could be listed: i) low scientific content and short time required for industrial solutions that do not encourage the partner to invest in S&T; ii) absence of appropriate interlocutors in companies what complicates the communication; iii) productive sector is not innovative enough; iv) absence of adequate instruments in universities for licensing technology; v) little flexibility of S&T institutions.

3. METHODOLOGY

To analyze the interaction between academic research and industry in Brazil the main data used in this paper was extracted from the Directory of Research Groups of CNPq (the Brazilian S&T Development Council) collected in the 2004 Census. Founded in 1951 inspired by the creation of the National Science Foundation in US, CNPq is an organization of the Brazilian Ministry of Science and Technology responsible for distributing research grants to the Brazilian scientific and technological communities. Its Directory of Research Groups is a database that started to be collected in the early nineties and is renewed every second year. It comprises detailed information about research activities in Brazil using the ´research group' as the unity of

[7] Among premises of this law is the sharing of infrastructure, participation of researchers in profits on the products created by the institutions, temporary transfer of ICT's researchers for companies and government granting of financial, human and infrastructure resources for companies to support its R&D activities.

analysis. The directory provides an excellent proxy for studying research activities in Brazil, even though the adherence to it is voluntary. In fact, since the late nineties coordinators of research groups in public universities have been implicitly forced to send information to the directory since their access to government funding implicitly depends on the information they send. Although there are intrinsic limitations to information collection, the database supplies some importance evidence from recent university-industry interactions in Brazil.

CNPq's Directory of Research Groups was first set up as an attempt to gather and organize information regarding research activities in Brazil. In the first version of the directory, in 1993, 99 institutions and 4.402 research groups informed about their research activities. The last version, of 2004, which is used in this analysis, comprises information about 375 institutions and 19.470 research groups. The total number of researchers is 77649, of which 47973 (62%) holding a PhD degree. According to some estimates (CARNEIRO & LOURENÇO, 2003), at least 85% of total researchers in Brazil are included in the database. In 2004, 52% of research groups were located in the Southeast (the richest region of Brazil). Twenty-two percent of groups were located in the South, 6% in the Center-West, 14% were in the Northeast and 4% in the North, the poorest areas.

From total research groups only 2139 (11.1%), affiliated to 217 institutions, declared any relationship with productive sector in 2004. The analysis hereafter will concentrate on these groups and in the information provided by them. Head of registered groups were asked, first to inform if the group itself initiated the relationship or if a firm approached the institute. The data base methodology proposes 14 types of possible relations between groups and firms. Each leader could list at most 3 types of relationship that were more frequent with firms. Research groups to firm's relationships could be of 9 different types. Firms to group relationships could be of 5 kinds. There were no relevant criteria or scale, so a comparison with other key studies (such as Meyer-Kramer & Schmoch, 1998; Klevorick *et al.*, 1994; Cohen *et al.*, 2002) is not possible.

Box 1 brings a list of possible relationships. The numbers 4 and 12 were excluded in the subsequent analyses as they do not comprise collaborative relationships. To simplify the analysis some relationships were gather to enhance the database information. The relationships 2 and 10 were gather to non-routine engineering activities, 3 and 11 to software development; 7 and 13 to technology transfer, and 8 and 14 to training. So these relationships are bilateral flows of knowledge and service between universities and firms.

Box 1: Types of relationships of research groups with firms

From research groups to firms	
1	Technical consultancy
2	Non-routine engineering (including prototype development and pilot plants)
3	Software development
4	Supply of inputs and materials not linked to joint projects
5	Scientific research (for immediate use of results)
6	Scientific research (not for immediate use of results)
7	Technology transfer
8	Training (including "on the job")
9	Others
From firms to research groups	
10	Non-routine engineering (including equipment development)

11	Software development
12	Supply of inputs and materials not linked to joint projects
13	Technology transfer
14	Training (including “on the job”)

Source: CNPq Directory of Research Groups, Census 2004.

Póvoa (2007) sent a questionnaire to CNPq’s research group’s leaders that declared to have transferred technology to firms in order to evaluate the mechanisms involved in the technology transfer process from universities to firms. A total of 271 questionnaires were returned (from a total of 969) belonging to 178 group’s leader (from 558). Some results of this survey concerning the features of technology transfer process in the four investigated sectors are analyzed in the last part of the present paper.

Information used in the analysis also comes from PINTEC, the Brazilian innovation survey carried by IBGE at firm level. PINTEC represents a pioneer experience in producing technological innovation indicators for the Brazilian industrial firms as a whole, being statistically representative for the main geographic regions of Brazil and focusing on the factors that influence the innovative behavior of Brazilian firm. A special tabulation of data extracted from PINTEC (2003) allows identifying innovative firms that have judged their relationships with universities in the innovation process particularly "relevant" in different industrial sectors.

Table 1 shows some evidences about university-industry relations and the innovative performance of firms inserted in industrial sectors. According to these figures, the innovative activity is more intense in ‘science-based’ and ‘supplier specialized’ sectors[8], particularly in electro-electronics and metal-mechanical, drugs and chemicals. The first set of sectors are responsible to a large extend of technical progress generation and transmission toward others economic activities. The majority of Brazilian innovative firms do not based their strategy in cooperative arrangements. In terms of cooperation with university the picture points toward a sub-utilization of national S&T infrastructure. Although, interactions with universities were considered ‘important’ and ‘very important’ by firms that engaged in this relationship. In drugs this percentage was 42%. As the general rule, the universities were seldom considered as important source to product and process innovation. As is shown in several papers, the most used channel of information by Brazilian firms were those from production chain links, as the ones with clients and suppliers (IPEA, 2005).

[8] See Pavitt’s taxonomy (1984).

TABLE 1: Firms, innovative firms, R&D expenses/revenue, innovation expenses/revenue, university as important source to innovation, innovative firms with cooperation (total and with university)

SECTORIAL ACTIVITY	Total firms(9)	Innovative firms number	Innovative firms %	% innovation expenses /revenue	% R&D expenses/ revenue	% univ. important source of information	% innovative firms with cooperation with universities
WOOD AND FURNITURE	**12,176**	**3,744**	**30.75**	**2,43**	**0,31**	**7.58**	**0.47**
CHEMICALS & DRUGS	**3,802**	**1,900**	**49.97**				
Chemicals	3,180	1,574	49.97	2,18	0,51	22.27	5.82
Drugs	622	326	49.51	4,16	0,72	42.41	11.13
METAL-MECHANIC	**26,420**	**8,981**	**33.99**			**14.85**	**3,54**
Metallurgy	1,470	676	46.00	2,03	0,18	14.72	2.51
Machines and equipments (M&E)	5,799	2,282	39.35	4,15	0,55	14.92	3.34
Metal products	8,573	2,668	31.12	3,01	0,21	7.14	0.35
Vehicle	2,214	819	37.02	4,42	1,25	8.76	2.45
Other transport equipments	589	205	34.77	6,08	3,22	8.24	1.73
Office and informatics M&E	211	146	69.2	3,85	1,48	28.59	9.34
Medical and industrial instruments	921	627	68.05	5,29	2,26	26.23	6.44
Non-Metallic Mineral Products	6,643	1,558	23.45	3,29	0,36	10.27	2.18
ELECTRO-ELETRONIC	**2,349**	**1,232**	**52.44**			**17.74**	**7.86**
Electrical M&E	1,982	865	45.73	3,45	1,29	13.25	5.04
Communication and electronic equipments	644	367	56.95	5,21	1,10	22.24	10.69

Note: (4) comprises firms with more than 19 employees.
Source: Pintec (2003), authors' elaboration.

4. UNIVERSITY-INDUSTRY INTERACTIONS IN FOUR INDUSTRIAL SECTORS

4.1 Chemicals and Pharmaceuticals

The chemical-pharmaceutical sector is characterized from an intense outside efforts to innovation. Compared with expenses oriented to the acquisition of external R&D which reached an amount of R$561 thousands per firm for the industrial sector as a whole, comprising 1.202 innovative firms, each one of the 124 innovative firms of the chemical and pharmaceutical sectors have spent an amount of R$ 930 thousands with those expenses, as is show by PINTEC (2003). Innovative firms from chemical and drugs comprise almost 50% of total. Firms that considered university an important[10] source to innovation were, respectively, 22% and 42% (table 1).

The mean of relationships with universities established by industrial firms in those sectors comprises 2,5 relationships per firm. The predominant interactions between firms and research groups in theses sectors were scientific research for immediate use of results and technology transfer. The first relationship reflects some efforts to establish a common language, and the

[9] Comprises firms with more that 19 employees.
[10] Embrace firms that considered universities as 'moderately' and 'very important' as innovation's sources.

second requires more efforts from one side. In third place appears scientific research without immediate use, what can be assumed to have at least a medium run horizon. This pattern can be explained by firm's behavior in this sector, as 27% of the innovative effort was thought inside and outside R&D activities. This framework suggests that in this sector the innovative process maybe relies in efforts to plan.

The firms from this sector interact with groups in specific scientific areas as it is show in table 2. The principal areas were pharmacology, chemical engineering, chemical and material and metallurgical engineering (these four scientific areas respond to 54% of total relationships). The groups from pharmacology involved in these collaborative linkages are specialized in drug's test and in new drugs improvement. The more frequent relationships were scientific research for immediate use of results what reflect the specific contribution of this scientific discipline in firms exclusively from drugs sector. Another feature is the small number of groups connected with new drug's development that is below than 10.

In chemical engineering the predominant relationships follow sector's pattern. However, this area concentrates the major number of scientific research without immediate use of results relationships. This suggests that the development of new productive techniques requires long time and complex cooperative linkages. In chemistry, the predominant relationships were scientific research for immediate use relationships, technology transference and technical consultancy. In material and metallurgical engineering interactions are concentrated in few groups that in average had three relationships with firms. A particular feature of this area is that the predominant relationship was technology transfer. Investigation in group level shows that the interactions were towards development and improvement of production process.

4.2 Metal-mechanical

The metal-mechanical sector embraces diversified activities since complex manufacturing activities towards manufacturing activities that the knowledge and techniques are widely spread. This sector is characterized as an input supplier to other sector's production process and by constant efforts to improve technology towards client's requirement. In technology complex sectors the search for innovations reflects in more intense interactions with universities and research institutes. Although this effort varies across branches: in machines and equipments effort are toward machine and equipment acquisition and inside R&D activities; in transport equipment, effort are toward R&D and knowledge acquisitions and inside R&D activities and in metallurgy the efforts are in machine and equipment acquisition.

Data from PINTEC shows 26,420 firm (table 1) in metal-mechanical sector and 8,981 innovative firms (33.99%) during 2001-2003. In innovative firms set, 14.85% considered universities as important source to innovation, although this behavior varies across sectors. In medical instruments and industrial automation it is 26%, in machine and equipments it is 15% and in metal products it is 7%. O gasto médio na aquisição externa de P&D do setor foi de R$ 714 mil, segundo informações da PINTEC. The firms from metal-mechanical sector (278 in total) interact with 183 groups in specific scientific areas as it is show in table 2. The principal areas were material and metallurgical engineering, mechanical engineering, electrical engineering, production engineering, civil engineering and computer science.

Material and metallurgical engineering comprises major number of interactive groups. Only three groups interact with 89 (32.2%) firms. These groups are involved in training human resources towards production process optimization, development of new materials in labs and in testing procedures of the structural features of materials. Relationships based in scientific research for immediate use of results are associated with transformation and development of materials and new materials. Sectors with intense interaction were: metallurgy, machine and equipments and vehicle/trucks. This information suggests that universities are present in the process of developing frontier innovation. Although this capacity is concentrated in few research groups that transfer knowledge more by one side flow (technology transference) than by joint research development.

In mechanical engineering, only three universities account for 40% of total relationship. These interactions were geographically bounded and these groups are located in two states (Minas Gerais and São Paulo). The more frequent relationships were scientific research for immediate use of results and technology transfer. Sectors with intense interaction were metallurgy, machine and equipments and vehicle/trucks.

In production engineering the competence of groups involved are in process optimization, production organization, logistic and information systems applications. The principal relationship was scientific research for immediate use of results (35% of total relationships) and training that accounts for 15% of total relationships. Scientific research not for immediate use of results and technology transfer were almost irrelevant. Sectors with intense interaction were: machine and equipments, metal products, vehicle/trucks and metallurgy. In civil engineering the majority of interactions were between firms and groups from Minas Gerais State, what accounts for 50% of total relationships. On average, each group had three relationships with firms. The more frequent relationships were scientific research for immediate use of results and technology transfer.

4.3 -Electro-electronic

The electro-electronic sector embraces two activities: (i) manufacturing of electrical machine and equipment; (ii) manufacturing of communication, optics and electronic equipments. The highest complexity of technical knowledge necessary for production and innovation in these sectors reflects in a narrow industrial park. Firms in electro-electronic sector comprise 2,349. Innovative firm in 2003 were 1,232 (52% of total firms). On the average, 17% of innovative firms considered universities as important sources to innovation and 8% had cooperative relationship with universities by PINTEC's database (table 1). O valor do dispêndio médio das 96 firmas que gastaram recursos com a aquisição de P&D externo foi de R$ 1,605 thousands. From CNPq Directory 127 firms from electro-electronic sector had 351 relationships with 111 research groups, what account to 2.7 relationships to firm on average (table 2). The principal academic areas were electrical engineering, computer science and material and metallurgical engineering.

In electrical engineering, the groups from two universities and one research institute comprise 34% of total relationships with firms. In this, interactions are geographically widespread, what can be explained by research groups' excellence in solving problems in firms' production processes. Groups' competences are in electronic micro-structures, in systems toward controlling motor's potency and in automation in agriculture.

In computer science interactions were restrict to a small number of groups (20) and firms (21). The groups from two universities in the South of Brazil account for 48% of total relationship, pointing to an excellence in the area of improving computational machines performance. The more frequent relationships were software development, scientific research for immediate use of results and technology transfer. In terms of sector 98% of total firms were from informatics, electronics and optical equipments.

In material and metallurgical engineering groups' competences are in developing electrochemical techniques to improve the features of materials used in production process and in new products. Around 50% of total relationships were technical consultancy and technology transference with groups from a research institute also located in the South of Brazil.

4.4 Wood and Furniture

The wood and furniture sector is composed by 5,089 firms from wood sector and 7,087 from furniture sector. The 3,744 innovative firms embrace 30.7% of total firms in wood and furniture sector. From innovative firms, only 7.5% considered universities as important information's source to innovation and 0.47% had cooperative linkages with universities. This result in some way was expected as the knowledge and technical base in this sector are widespread. In this sector 70% of total expenses in innovation, were toward machine and equipment acquisitions. Expenses for outside firm's R&D and knowledge account for only 1.6% of total expenses in innovative activities. A media de gastos das 148 que dispenderam recursos para aquisição externa de P&D foi de apenas R$ 45 mil., muito abaixo da média geral

Data from CNPq show 65 relationships between 24 research groups and 28 firms (7 in wood sector and 21 in furniture). Interactions were, frequently, with groups from forestry engineering and mechanical engineering. The first probably reflects recent concern from large firms towards environmental issues and technical requirements for exportation. The more frequent relationship were scientific research for immediate use of results and technical consultancy. In mechanical engineering, technical consultancy was towards improvements in product's features and in the production process. In civil engineering the main relationship were technology transference, and the data suggests that it's for suiting technical securities problems against fire, and others social demands.

Table 2: Total relationships, groups and firms with interaction and frequent relationship by principal scientific areas in selected sectors, Brazil, 2007.

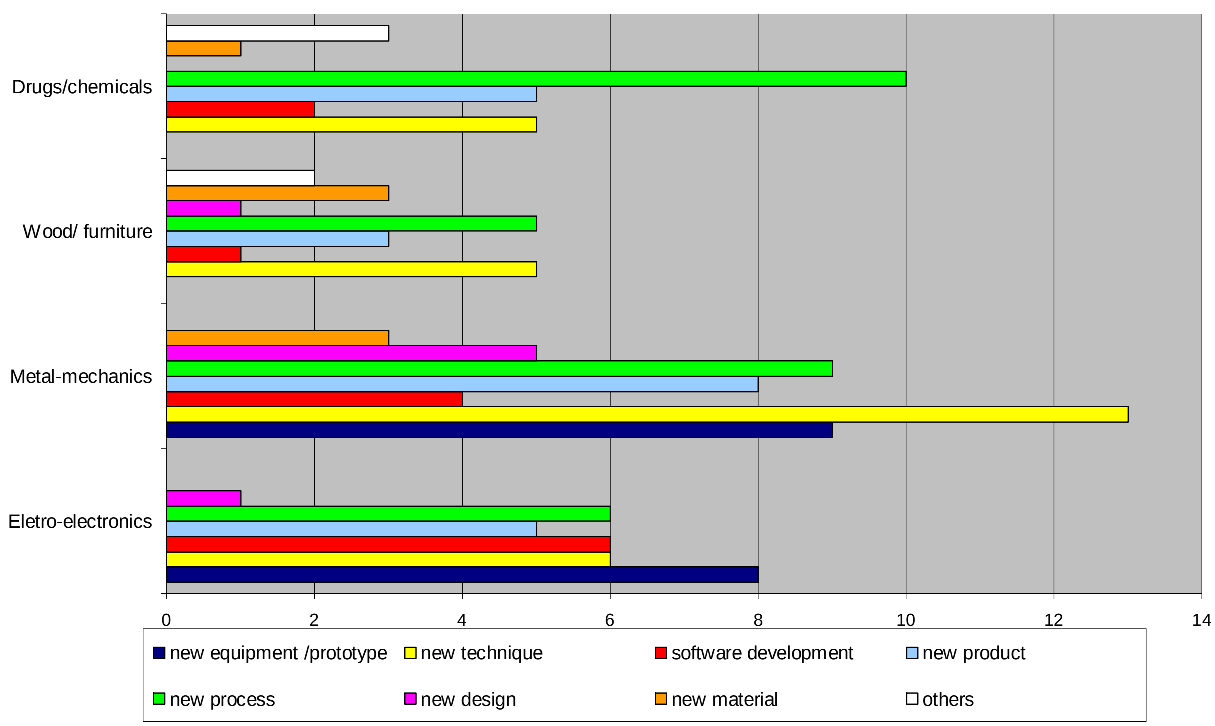
SECTOR	PRINCIPAL SCIENTIFIC AREAS	Total relationship	Groups with interaction	Firms with interaction	Frequent Relationship					
					scientific research not for immediate use of results	scientific research for immediate use of results	technology transfer	technical consultancy	non-routine engi.	Software Devel.
Drugs/ pharmaceutical	Pharmacology	104	26	49	11	46	20	19		
	Chemical engineering	94	24	37	17	41	21	2		
	Chemistry	68	28	37	8	25	18	14		
	Material and metallurgical eng.	51	17	41	7	10	28	6		
	Total (sector)	585	215	230	74	198	147	56		
metal – mechanical	Material and metallurgical eng.	332	52	177	48	89	94		32	
	Mechanical engineering	166	37	55	16	45	38		14	
	Production engineering	66	14	25	6	23	6		0	
	Civil engineering	53	18	18	6	15	12		6	
	Total (sector)	720	183	278	88	211	151		80	
electro-electronics	Electrical engineering	130	32	50	19	31	17	5	25	7
	Computer science	76	20	21	6	15	20	3	8	17
	Material and metallurgical eng.	43	10	27	5	8	9	12	3	0
	Total (sector)	351	111	127	40	76	73	27	53	33
Wood / furniture	Forestry engineering	29	12	10	7	3	3	8		
	Mechanical engineering	13	2	7	0	0	10	1		
	Civil Engineering	12	5	5	2	1	5	2		
	Total (sector)	65	24	28	10	4	18	15		

Source: CNPq's Directory of Research Groups, 2007, author's elaboration.

4.5 - Technology Transference in four sectors

The database in this section is from Póvoa (2007)'s work described in the methodology. From the 271 questionnaires answered, 18 were from electro-electronics, 7 from wood and furniture, 29 from metal-mechanicals and 21 from drugs and chemicals. Graph 1 shows the type of technology developed by research group's and transferred to firms in those four industrial sectors. The figure shows sectors specificities in terms of technology transferred from universities to firms. Each sector received different types of technology from universities. In drugs and chemical the main technology transferred by universities was new process, in metal-mechanicals new technique and in electro-electronics new equipment/prototype. In wood and furniture new techniques and new process had the same frequency. New process and new equipment/prototype were also relevant in metal-mechanical, as was software development, new techniques and new process in electro-electronics. In other way, new material was not present in electro-electronics, as was design in drugs and chemicals. In al sectors new processes were more frequent than new products.

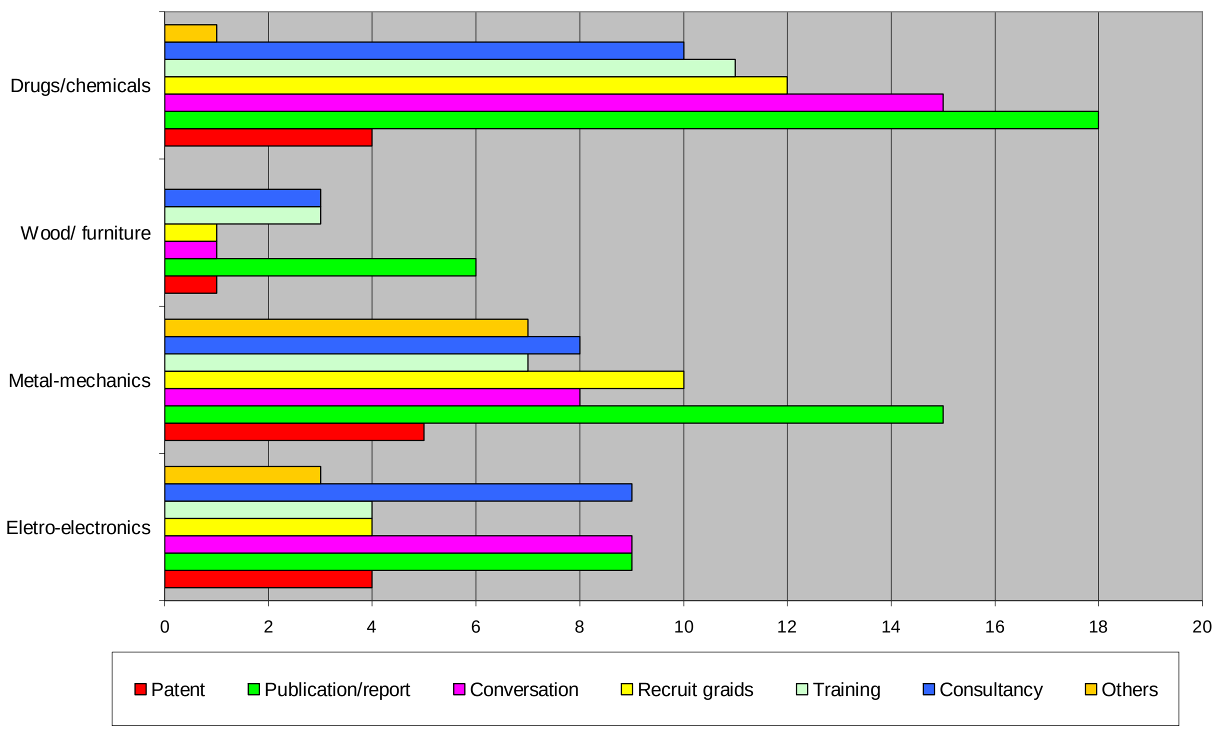
Graph 1: Type of technology transferred in four industrial sectors, Brazil, 2006.



Source: authors' elaboration.

Graph 2 shows the channels of technology transfer from universities to firms in the four industrial sectors. In all sectors the main channel used was publications and reports. In drugs and chemical the transfer occurred also by conversation and recruitment of grad students. In electro-electronics, consultancy was also an important mechanism to transfer technology. In wood and furniture training was a relevant channel. Surprisingly, patents were not a frequent channel to transfer technology in these sectors, being an exception electro-electronics. These two graphs reinforce that each sector has distinct characteristics that should be taken into account when analyzing the knowledge and technology flow between universities and firms.

Graph 2: Channels of technology transferred in four industrial sectors, Brazil, 2006.



Source: authors' elaboration.

4.6. Sectorial patterns of U-I interactions

In the chemical and pharmaceutical sectors the expressive number of innovative firms and its relatively high expenses oriented to the external acquisition of P&D had resulted in intensive U-I relationships oriented to scientific research, especially when they involve interactions with research groups in the areas pharmacology, chemistry and chemical engineering. In this sense, we can stress the importance of cooperative links between of industrial laboratories with research groups in the area of pharmacology to develop studies about the properties of the native flora and fauna. Concerning the transfer of knowledge and technologies among the two spheres, its was registered a stronger intensity of relationships with research groups specialized in the areas metallurgy, chemical engineering and new materials. The main focus of these relationships was the transfer of new production process and new productive techniques developed with the support of those scientific areas to some segments of the chemical industry. The channels mobilized to permit the transference of those technologies presented a high diversity, intensively involving formal as well as informal mechanisms.

In the electro electronics sector, it was also observed a high number of innovative firms, as well as an expressive amount of financial resources oriented to the external acquisition of R&D. However, the intensity of U-I relationships based on scientific research without immediate concern with results was followed by relationships that incorporated mechanisms of technology transfer, as well as by interactions based on the development of non routine engineering. This diversity varies according to the areas of the knowledge where the research groups are specialized. In the area of electric engineering U-I relationships tend to involve scientific research and non-routine engineering, while in the area of new materials and metallurgy the knowledge of research groups tend to be transmitted through technical consultancy. The process of technology transfer and the development of software had presented greater frequency when the interactions had occurred with specialized research groups in the area of computers engineering. In this sense, the mechanisms more frequently used to permit the process of technology transfer had been the training of the industrial staff, informal colloquies between the parts involved and technical consultancy, involving, over all, the development of new prototypes, new production techniques and new software. According to Guinter (2006), *brain drain* processes tend to be more intense in the broader area of engineering, representing a challenge to the maintenance of research groups; on the other hand, these processes tend to reinforce the mechanisms of technology transfer previously mentioned.

In the metal-mechanics sector, the intensity of innovative efforts developed by industrial firms and amount of amount of financial resources oriented to the external acquisition of R&D tend to be quite similar to the general pattern of the industrial sector as a whole, involving a complex mix of U-I relationships, in which scientific research are often combined with mechanisms of technology transfer. The interactions involving scientific research were intensive with anyone of the four knowledge areas analyzed. This pattern suggests that the development of technological innovations in these disciplines demands mutual efforts in the scientific and technological spheres, often oriented to a long run perspective. Its is interesting to note that, despite the limits of efforts oriented to external acquisition of R&D, the sector as a whole reached a mean of 2,6 relationships per firm, stressing the multiplicity of U-I interactions in those activities. Technology transfer occurred through diverse channels, which can be explained by the diversity of the industrial segments in that sector, including since basic metallurgy until the construction of sophisticated equipment for the automotive industry.

The sector of wood and furniture was the only of the analyzed sectors in which the percentage of innovative firms and the amount of expenses oriented to the external acquisition of R&D are bellow the general mean of the industrial sector. This pattern is marked by U-I relationships oriented to technology transfer, involving research groups in the area “mechanical engineering”, as well as technical consultancies of research groups in the area of “forest engineering”. In this process, the economically useful knowledge are generated in the sphere of S&T and spread out to the firms capable to absorb this knowledge, rarely involving the necessity of mutual efforts and strong interactive ties between the agents. This occurs due to the ample diffusion of the basic knowledge that is necessary to produce and generate innovations in the sector. The technology transfer had been carried through structured channels, such as publications, training of the industrial staff and technical consultancies, focusing the development of new products and new productive techniques

Conclusions

The exploratory analysis developed tried to identify the main characteristics of the technological efforts of the innovative firms inserted in the chemical-pharmaceutical, metal-mechanical, electro-electronics and wood-furniture sector of the Brazilian economy. The results points to specific contributions of universities and research labs to innovation in firms and to sectorial patterns of collaboration. Its was also observed some general characteristics of Brazilian national innovation system that are broadly disseminated among the industrial sectors, such as the limited number of industrial firms effectively involved with innovative activities.

The analysis developed reveals that the intensity of sectorial innovative efforts oriented to the acquisition of external R&D tends to be positively associated with U-I interactions that involve scientific research. The acquisition of external R&D is usually connected to internal R&D efforts, in order to absorb the knowledge generated in the different spheres. Considering the limited amount of these efforts in Brazilian industrial sectors, we can conclude that the existence of structured networks integrating research groups and industrial firms is still limited in Brazilian economy. This characteristic is consistent with the actual stage of development of the Brazilian national innovation system, partially reproducing a trend broadly observed in mature NISs.

However, the analysis also points out some sectorial specificities related to the pattern of U-I relationships in Brazilian economy. Those specificities result in normative implications that might be considered in order to permit the catching up of Brazilian national innovation system. A strong diversity in terms of university-industry interactions was observed given the great specificity of sectors' analyzes. We had also observed that the channels and the mechanisms of technology transfer tended also to be modulated by sectorial specificities. In this sense, the deepening of the understanding of sectorial patterns of U-I relationships seems to be a subject of a promising research agenda.

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References

AROCENA, R.; SUTZ, J. Knowledge, innovation and learning: systems and policies in the north and in the south. In: CASSIOLATO, J.E; LASTRES, H.M.M; MACIEL, M.L. (eds.) *Systems of Innovation and Development – Evidence from Brazil*. Edward Elgar, 2003.

ARUNDEL, A.; GEUNA, A. Does proximity matter for knowledge transfer from public institutes and universities to firms? *SPRU Electronic Working Paper,* N.73, 2001.

BITTENCOURT, P.F.; RAPINI, M.S; BRITTO, J. CASSIOLATO, J. E. The relations between firms and universities in Brazilian innovative regions: an exploratory study. IN: 5th *Globelics International Conference*. Russia, 2007.

CARNEIRO, S. J.; LOURENÇO, R. Pós-Graduação e Pesquisa na Universidade, In: VIOTTI, E. B.; MACEDO, M. (Org) *Indicadores de Ciência, Tecnologia e Inovação no Brasil*, Campinas: Editora da Unicamp, 2003, Chapter 4, p.169-227.

CASSIOLATO, J.E.; RAPINI, M. S. University- industry interactions: Evidences from lest developed countries. IN: *II Globelics Conference: Innovation Systems and Development*, *Emerging Opportunities and Challenges*, October, 16 a 20 de Outubro, Beijing, China, 2004.

COHEN, W. M.; NELSON, R. R.; WALSH, J. P. The influence of Public Research on Industrial R&D. *Management Science*, v. 48, n.1, p.1-23, January, 2002.

CNPq. Conselho Nacional de Desenvolvimento Científico e Tecnológico, 2005.

ETZKOWITZ, H.; LEYDESDORFF, L. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy*, v. 29, pp. 109-123, 2000.

FAGERBERG, J.; GODINHO, M. M. Innovation and Catching-up. IN: *The Oxford Handbook of Innovation.* (eds) FAGERBERGER, J.; MOWERY, D. C.; NELSON, R.R. Oxford: Oxford University Press, 2005, p. 514-542.

KLEVORICK, A. K.; LEVIN, R.; NELSON, R.; WINTER, S. On the sources and significance of inter-industry differences in technological opportunities. *Research Policy*, v.24, n.2, p.185-205, March, 1995.

LUNDVALL, B. A. The University in the Learning Economy. *DRUID Working Paper No 02-06*, 2002.

MELO, A. *Innovation systems in Latin America*. Washington, DC: Inter-American, 2001.

MEYER-KRAMER, F.; SCHMOCH, U. Science-based technologies: university- industry interactions in four fields. *Research Policy,* v.27, n.8, p. 835-851, December, 1998.

MOWERY, D.; SAMPAT, B. Universities in national innovation systems. *In* FARGERBERG, J; MOWERY, D.; NELSON, R. (Editors) (2005) *The Oxford Handbook of Innovation*. Oxford University Press, 2005.

OCDE. Benchmarking Industry-science relationships, 2005.

PAVITT, K. Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. *Research Policy*, v. 13, October 1984, p. 343-373.

POVOA, L (2006) Technology Transfer from Universities and Public Research Institutes to Firms in Brazil: What and How they Transfer. IN: *IX Encontro de Economistas de Língua Neolatina***,** Rio de Janeiro, 2007.

THORN, K.; SOO, M. Latin American Universities and the Third Mission: Trends, Challenges and Policy Options, *World Bank Policy Research Working Paper 4002*, August 2006.